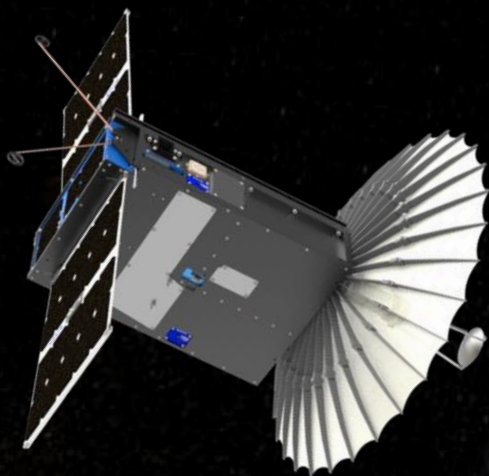




# RainCube

## Ka-Band Precipitation Radar in a 6U CubeSat

**31<sup>st</sup> Annual AIAA/USU Conference on Small Satellites**  
**August 2017 – Logan, Utah**



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RainCube is a ***technology demonstration*** mission to enable ***Ka-band*** precipitation radar technologies on a low-cost, quick-turnaround platform.

- **InVEST-15 Selection, ESTO**

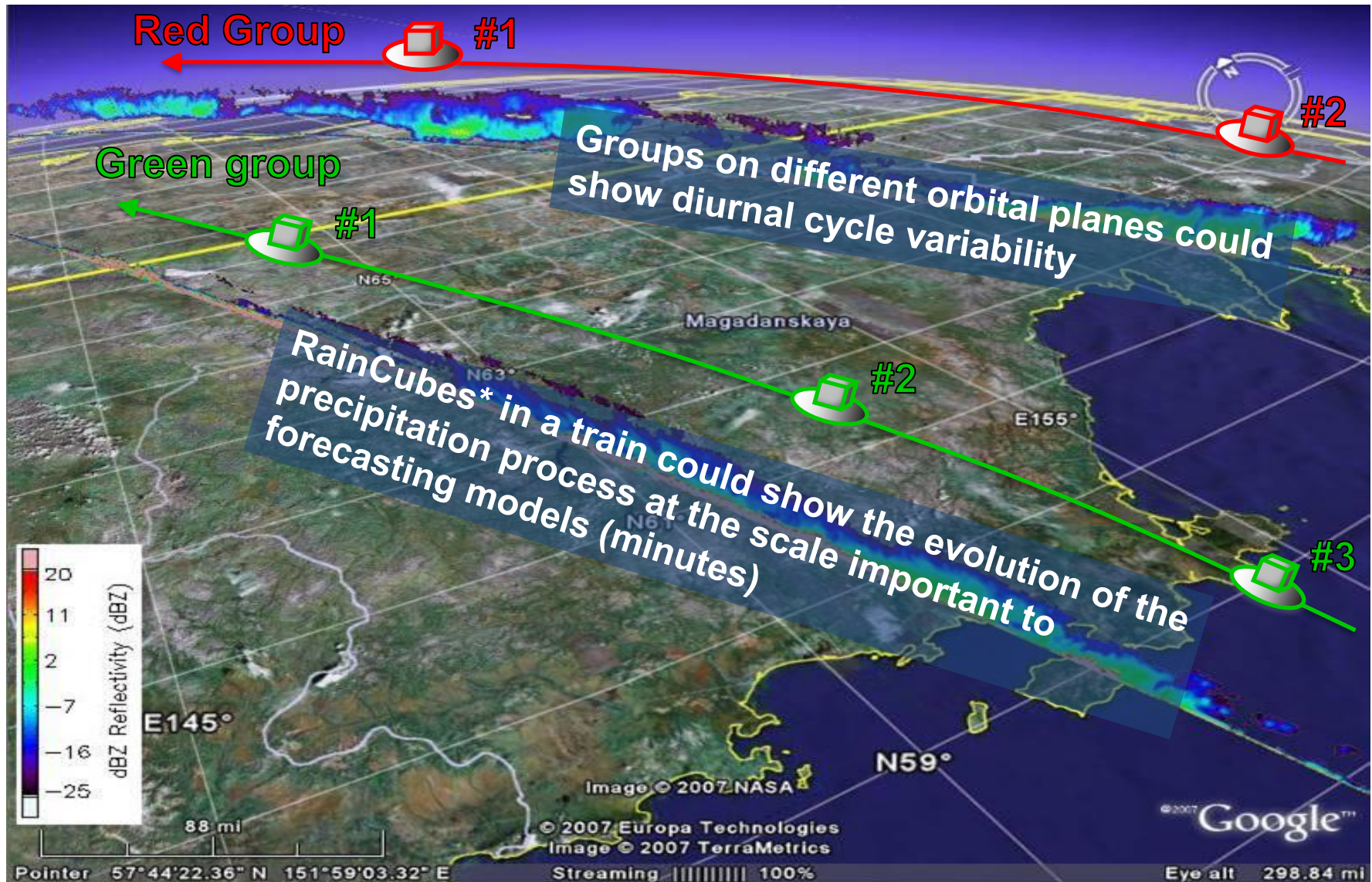
- Validate new Earth science technologies in space (TRL 4 to TRL 7)
- 6U CubeSat, deploy to LEO from ISS
- Three month primary mission (1 month payload demo phase)
- Launch date is March 14, 2018 (T-7 months!)

- **Two Key Mission Objectives**

- Demonstrate new technologies in Ka-band on a CubeSat platform
  - Miniaturized Ka-band Atmospheric Radar for CubeSats (miniKaAR-C)
  - Ka-band Radar Parabolic Deployable Antenna (KaRPDA)
- Enable precipitation profiling radar missions for Earth Science

- **Roles & Responsibilities**

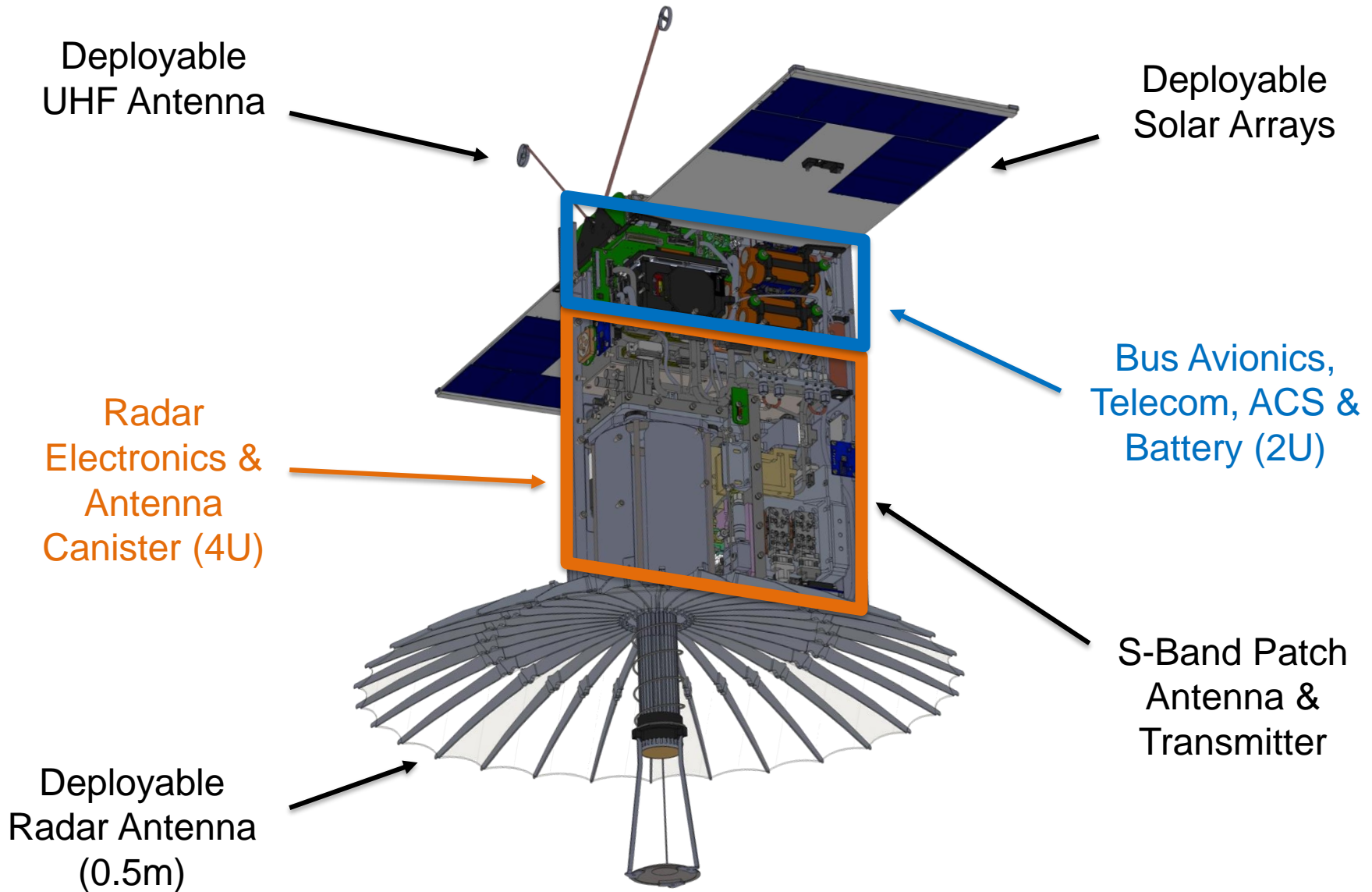
- NASA ESTO: Sponsor
- JPL: Project Management, Mission Assurance, Radar Delivery
- Tyvak: Spacecraft Delivery, System I&T, Mission Operations



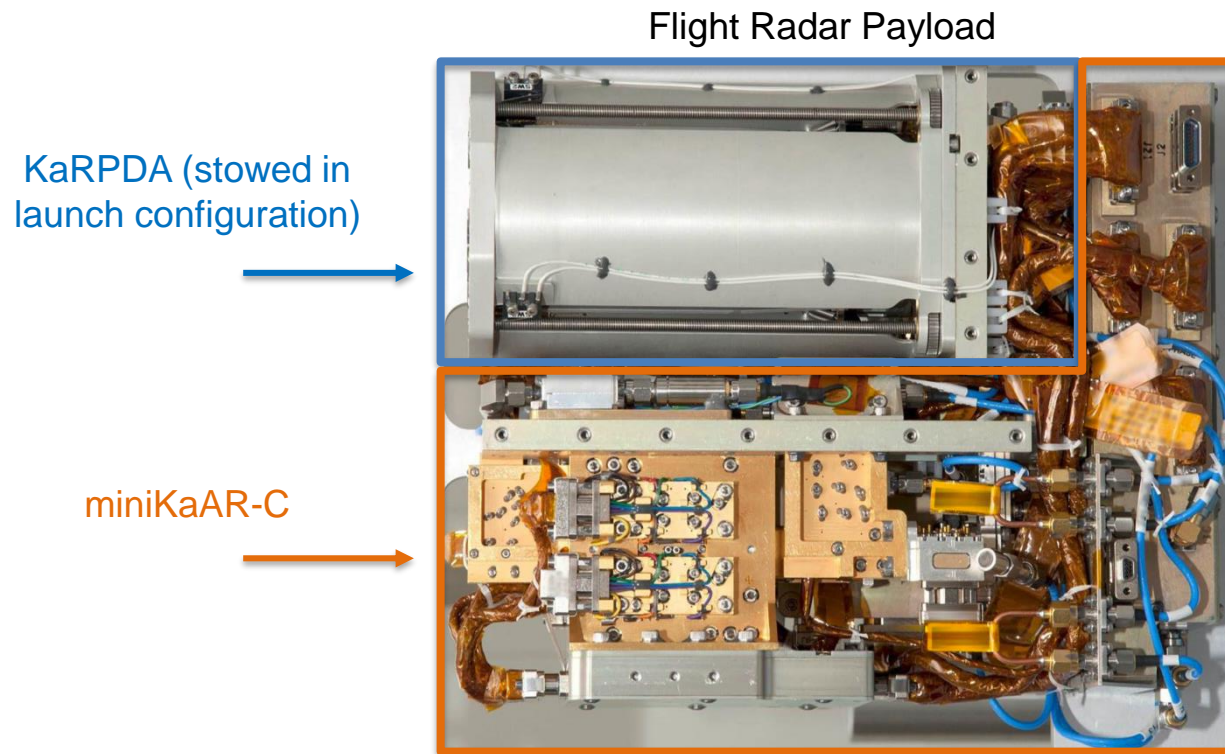
\*Mission Concept – Pre-decisional – Planning and Discussion Purposes Only

RainCube, a Ka-band Precipitation Radar in a 6U CubeSat

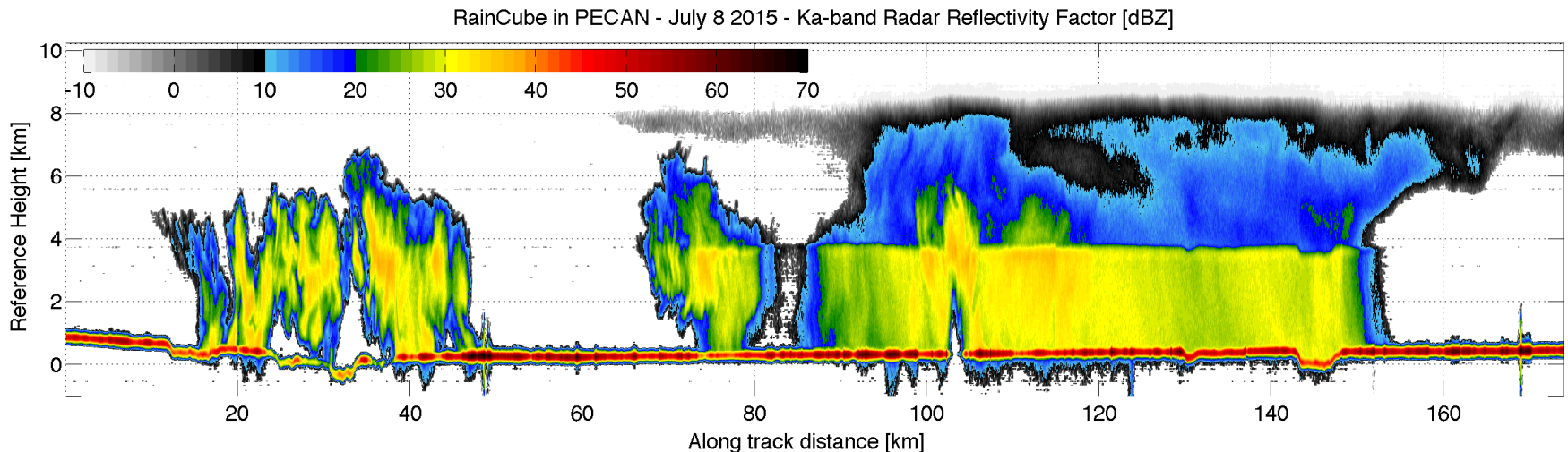
- Radar
  - Vertically profile precipitation between 0 and 18 km altitudes
  - 250 m vertical resolution
  - 10 km horizontal resolution ( $\geq 0.5$  m antenna aperture)
  - Sensitivity  $\geq 20$  dBZ
- Spacecraft
  - Provide 35 W for payload power (transmit mode)
  - Maintain 25% payload duty cycle in transmit mode
  - Operate payload through continuous orbits (1 orbit in transmit)
  - Store and downlink 12.1 Gb payload data per week
  - Maintain payload temperatures (-5C to +50C operational)



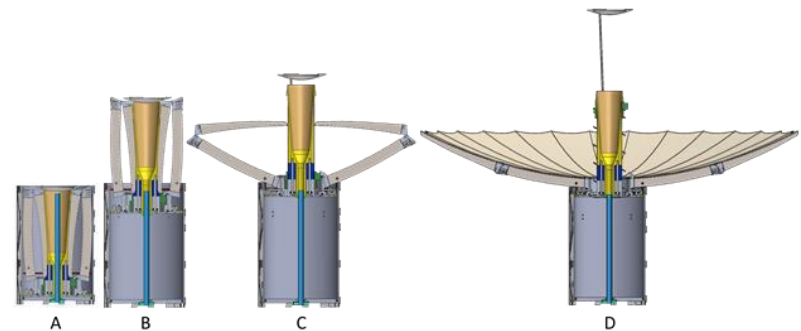
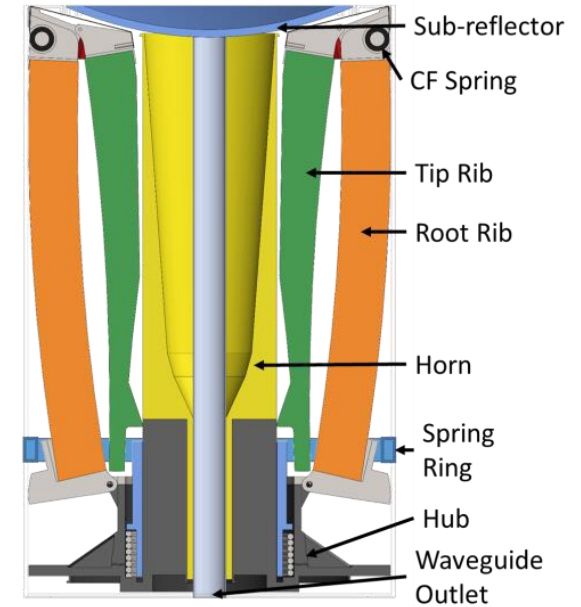
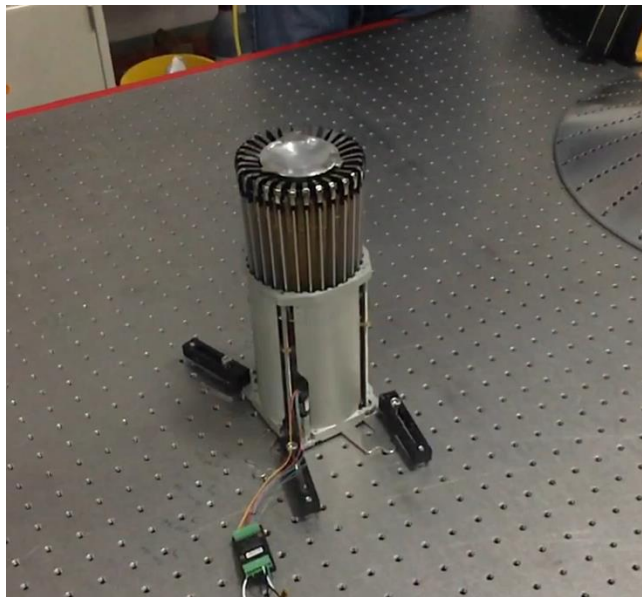
- Radar payload is comprised of two new technologies developed at JPL
  - miniKaAR-C (miniaturized Ka-band Atmospheric Radar for CubeSats)
  - KaRPDA (Ka-band Radar Parabolic Deployable Antenna)



- Novel radar architecture that greatly reduces size, mass, and power
  - Only 5 unique RF active components
  - One Ka-band and one 40 MHz oscillator
  - One digital board for control, timing, on-board processing, SC digital interface, etc.
- Critical elements were tested in a July 2015 airborne demonstration

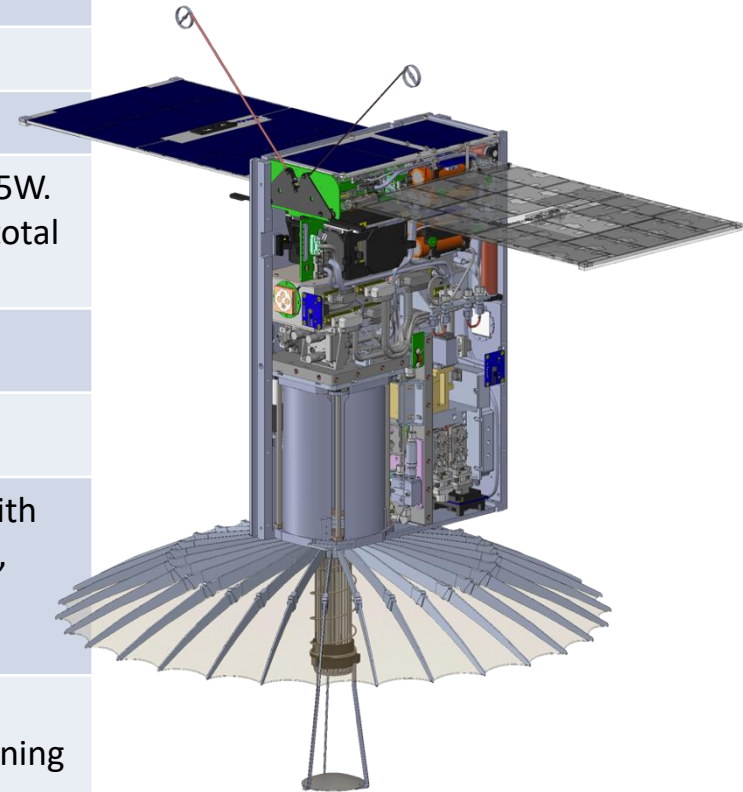


- Cassegrain architecture
- Motorized system with spring-loaded ribs and sub-reflector
- 0.5 meter dish that stows in ~1.5U

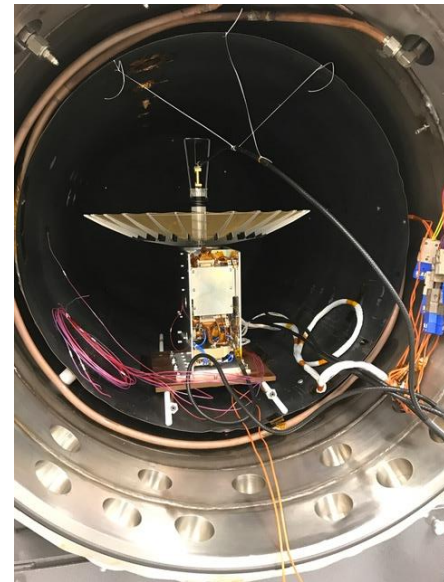
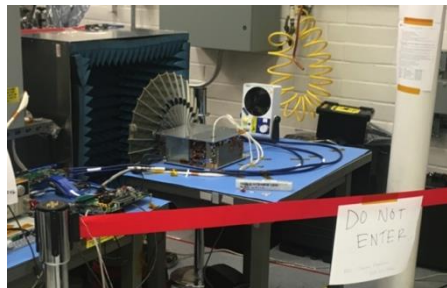
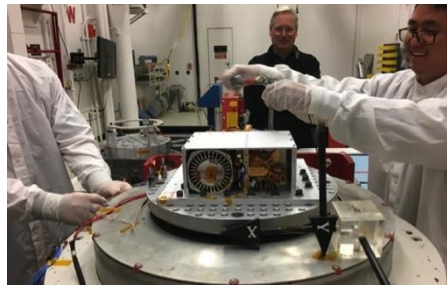
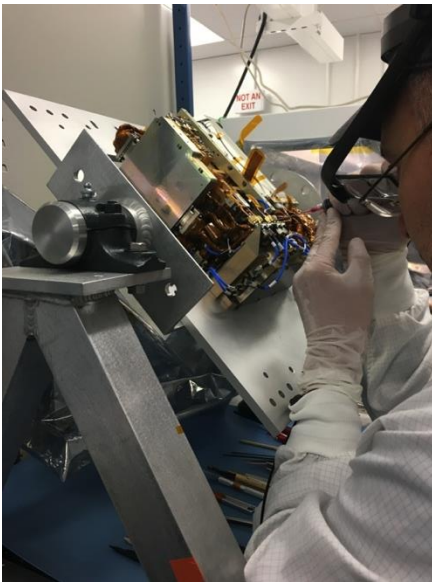


N. Chahat, J. Sauder, M. Thomson, R. Hodges, and Y. Rahmat-Samii, "CubeSat Deployable Ka-band reflector antenna development for Earth Science Mission," IEEE Trans. Antennas and Propagation, vol. 64, no. 6, pp. 2083-2093, June 2016.

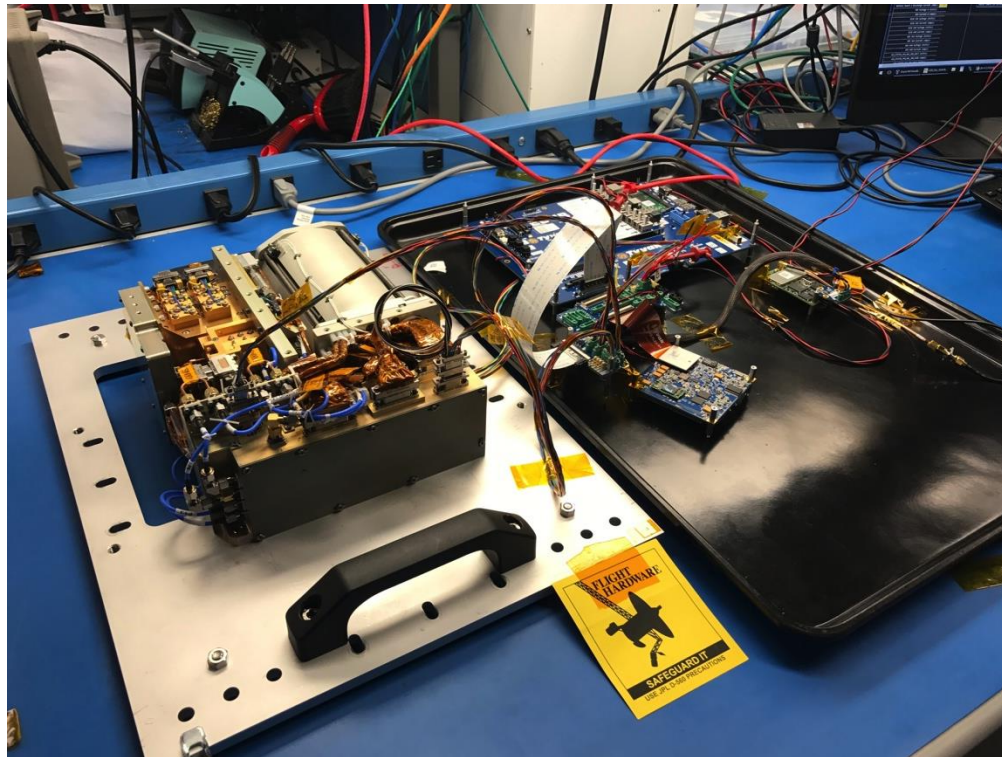
Subsystem	Value
C&DH Processors	ARM9, Tyvak Linux Build
ADCS Processors (x2)	ARM Cortex A8
Battery Modules	~70Whr batteries @ 11.1V Nominal
Solar Panels	Deployable Fixed Angle Arrays. Peak Power ~ 45W. Contingency cells on opposing face. Sixty-Five total XTJ Cells.
UHF Radio	Tyvak UHF Radio operating @ 19.2kbps
S-Band Radio	Quasonix NanoTX transmitter at 4Mbps
ADCS Control	0.029 degree control error (99.7 <sup>th</sup> percentile) with redundant star trackers, three reactions wheels, three torque rods, IMU, sun sensors, and magnetometers.
Thermal Control	Active battery and payload warmers. Passive conduction and radiating surfaces for the remaining avionics and payload.
Antennas	Phased GPS Patches, and deployable UHF, S-Band Patch, and Ka-Band Dish
GPS	Novatel OEM-615



- Completed radar assembly and test in March 2017
  - Functional and RF performance tests
  - Radar calibration over temperature (thermal-atmosphere)
  - Workmanship random vbe, protoflight thermal-vacuum (including antenna deployment)
- As-built measurements
  - 22 W power draw in transmit mode (versus 35 W allocation)
  - 5.5 kg total mass (versus 6 kg allocation)



- Delivered flight radar July 2017
- Completed first interface test of radar and SC
- System I&T underway



- **Aug '17:** System build and functional testing complete
- **Sept '17:** Environmental testing complete
  - Hardware goes into storage and prep for mission operations
- **Jan '18:** Mission Readiness Review
- **Feb '18:** Deliver satellite to NanoRacks
- **Mar '18:** Launch to ISS (OA-9 CRS Mission)
- **May '18 (est.):** Deploy from ISS
- **July '18 (est.):** Primary mission complete



- ESTO, Project Sponsor
  - Pam Millar
  - Charles Norton
- JPL Earth Science Program Office
  - Eastwood Im
- RainCube Team, JPL & Tyvak
  - Eva Peral
  - Travis Imken
  - Jonathan Sauder
  - Simone Tanelli
  - Douglas Price
  - Nacer Chahat
  - Austin Williams
  - Many more...

